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A NAVY DIVING SUPERVISOR'S GUIDE TO THE NONTECHNICAL SKILLS REQUIRED FOR SAFE AND PRODUCTIVE DIVING OPERATIONS

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19. ABSTRACT

Although the diving community is proficient in identifying and mitigating technical problems, it is not as adept in recognizing and reducing the nontechnical human factors errors that cause accidents. This guide aims to provide Navy divers with background information on the nontechnical skills required for safe and productive diving operations. The skills addressed are based upon extensive research of Navy diving mishaps.

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INTRODUCTION

Safety research has shown that human performance problems most heavily shape risks in hazardous industries: the greatest cause of approximately 80% of aviation mishaps is generally regarded as human error.[1,2] Although U.S. Navy diving is remarkably safe, because of the high-risk environment in which divers work, accidents and mishaps do occur. The Navy diving community is adept at identifying and mitigating technical problems; it is not as adept with the nontechnical or human factors that cause accidents. Little guidance to prevent or mitigate such accidents is available to its divers.

The purposes of this guide are to provide information on the nontechnical skills required for safe and productive operations by U.S. Navy dive teams. Nontechnical skills are required for safe and effective performance in a technical context but not directly related to technical expertise. The nontechnical skills addressed in this guide include situation awareness, decision making, teamworking/leadership, and mitigating the effects of stress and fatigue. Communication is not included as a separate topic, since it underpins every one of these skills.

The information provided is based on an analysis of 455 diving mishaps, 5 reports investigating fatal mishaps, 15 interviews with Navy divers, and 272 U.S. Navy diver responses to an attitude questionnaire.[3] The complete framework of nontechnical skills required for safe, effective diving operations from this research is in Appendix A. Information has also been drawn from other high-risk industries (e.g., aviation, nuclear power production, offshore oil production) relevant to Navy dive teams. Furthermore, real-world diving incidents in which failures in nontechnical skills were evident have been included.

SITUATION AWARENESS

DEFINITION

Situation awareness is an awareness of what is going on around you. Its lack comprises the greatest cause of Navy and Marine Corps aviation accidents. Formally defined, it is a "detection of elements in the environment within a volume of space and time. The comprehension of their meaning, and the projection of their status in the near future."[4] Models of situation awareness generally propose the following three levels (see Figure 1).[5]

Level 1: Basic. An awareness of the key elements in the situation — e.g., bottom time, depth, weather conditions, bottom report, sea state, repet groups of available divers, condition of divers, stage of the job.

Level 2: Intermediate. A comprehension and integration of the elements in light of the current operational goals — e.g., understanding that the divers are having difficulty completing the job, and that there are insufficient clean divers.

Level 3: Advanced. The ability to use the current information to predict what will happen in the future — e.g., the schedule will slip, different equipment is necessary, or an alternative technique is required to complete the task.

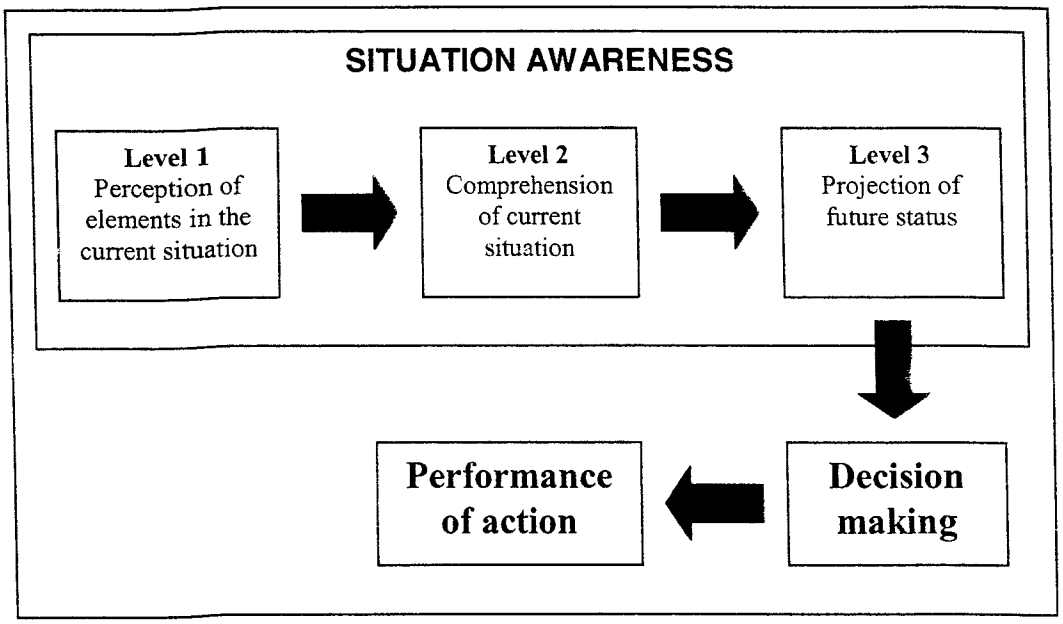

Figure 1. Model of situation awareness.

Levels 2 and 3 have been found to be particularly critical in complex environments such as diving. Failures in acquiring good situation awareness undermine the quality of any decision making and, ultimately, performance.

WHY IS SITUATION AWARENESS IMPORTANT TO NAVY DIVERS?

From an analysis of U.S. Navy diving accidents and near-misses, failures in situation awareness accounted for approximately 40% of all nontechnical failures. The most common failures resulted from errors in risk and time assessment and a lack of awareness of the status of the dive (see Appendix A). Furthermore, when Navy divers were asked to identify the most common cause of diving accidents, they named complacency as the most common.

MYTHS ABOUT SITUATION AWARENESS

Once the risk assessment is made at the beginning of the dive, there is no need to reassess.

Obviously a risk assessment should be carried out at the beginning of the dive. However, diving is a dynamic process, and risks change as a dive progresses. Therefore, it may be necessary to assess risks informally during a dive.

The Diving Supervisor needs to know everything that is going on.

This is partially true. However, to prevent overloading the Dive Supervisor, in an emergency or other high-stress situation the team members must be sensitive to the kind and amount of information that is required. Team members need to give the Dive Supervisor only the information pertinent to the emergency. They should endeavor not to overload the Dive Supervisor with irrelevant information.

MAINTAINING GOOD SITUATION AWARENESS

1. GET THE RIGHT INFORMATION

- Maintain an awareness of how a dive is progressing.
- Make extra efforts to get such information during abnormal situations and on descent and ascent.
- After an interruption or distraction, back up several steps from where you think you left off, or double check all steps.
- Be aware of environmental effects (e.g., temperature, sea state).

2. OVERVIEW

- Stand back and look at the problem.
- Double-check assumptions.
- Check assumptions with others.
- Stay focused on the goal, but avoid tunnel vision.
- Take time out and review objectively.
- Verbalize decisions.

3. REVIEW

- When possible, discuss how a particular situation was solved: identify both good and bad points.

An Example of Good Situation Awareness

Fifteen minutes into a MK 21 dive, the helmet came off one of the divers. The diver could not find the helmet and was almost out of air. He tried to climb up the umbilical; however, his attempts were futile.

The Diving Supervisor heard gurgling over the comms. The standby diver was deployed, and both he and the diver's buddy managed to recover the unconscious diver, who recovered fully.

The fact that the diver had not died can be attributed to the vigilance of the Dive Supervisor and the dive team, who had noticed the gurgling quickly and reacted to the situation.

QUESTIONS TO CALIBRATE SITUATION AWARENESS

It is suggested that periodically during a dive, you ask the following questions of yourself (this is particularly important for the Diving Supervisor):

- What is the immediate goal of your team?
- What are you doing to support that goal?
- What are your concerns?
- What do you think this situation will look like in __ minutes, and why?

DECISION MAKING

DEFINITION

The type of decision making strategy that is most appropriate in a given situation depends on the amounts of time and information available, the level of risk, and the expertise of the decision maker. Three decision making strategies are used by people in high-risk environments:[6]

- Analytical
- Rule-based
- Recognition-primed

ANALYTICAL DECISION MAKING

This method is used when time to come up with the best solution to a problem is plentiful. This method may involve thinking of a number of solutions, and then deciding which would effect the best outcome. Four steps in using this method include:

1. Identifying the problem.
2. Generating a set of options for solving the problem/choosing among the alternatives.
3. Using a number of strategies (e.g., comparing the relevant features of the options) to evaluate these options concurrently.
4. Choosing and implementing the preferred option.

This technique usually produces the best solution, and it is most valuable in solving new problems. However, it is slow, laborious, and affected by stress.

Positives	Negatives
• Usually produces the best solution. • Useful when trying to solve a novel problem.	• Slow. • Laborious. • Affected by stress.

RULE-BASED DECISION MAKING

This technique is used to solve familiar problems in which solutions are governed by written rules or procedures. Once the problem has been diagnosed, you need only to follow a series of rules. Therefore, you do not need to be an expert or to understand every step.

Positives	Negatives
• You do not need to be an expert. • You do not need to understand the purpose of every step.	• It is easy to miss a step in the sequence. • If the diagnosis is incorrect, you may blindly follow the wrong set of rules.

An Example of a Rule-Based Error

An experienced operator was completing the predive checklist for the MK 16 MOD 1. Each step of the procedure had been initialled on the predive checklist. However, when the rig was dove, the diver passed out almost immediately, and only through the quick reactions of the dive team was a death avoided. When the MK 16 was examined, it was found that an empty CO_2 absorbent canister had been installed during the predive.

The operator made a rule-based error and missed a crucial step in the predive checklist.

RECOGNITION-PRIMED DECISION MAKING

Recognition-primed decision making is a technique used by experts to make decisions in high-workload, time-limited situations. It is how experienced people make decisions rapidly. This technique is distinguished by

- Actions and reactions being based on past experience.
- The emphasis being on reading the situation, rather than on generating different options for possible actions.
- Experienced reading of a situation, so that the selection of a course of action is obvious.
- The generation of a solution that, while it may not be the best, should result in a resolution that is workable.

Positives	Negatives
• Is a useful method when time is limited. • Requires little mental effort. • Can provide a satisfactory, workable plan. • Is useful in routine situations.	• Can be applied only in certain situations. • Requires that the user be an expert. • Can encourage looking only for evidence to support one's model, rather than considering evidence that may not support that model (confirmation bias).

An Example of Recognition-Primed Decision Making on a Saturation Dive

A three-man civilian dive team was saturated at 300 feet of seawater (fsw) in the North Sea. The three divers had finished their work for the day and were being winched onto the oil platform to mate with the Deck Decompression Chamber (DDC). The Personnel Transfer Capsule (PTC) had cleared the water when a rogue wave hit the PTC and drove it into the underside of the platform. The force of the wave also drove the camera attached to the outside of the portal through the glass. The Diving Supervisor saw what had happened, heard the escaping gas, realized that the divers would be dead before he could mate the PTC and the DDC, and immediately hit the winch handle to drop the PTC back to 300 fsw.

Fortunately, the divers were able to scramble back into their dive gear and transfer into the PTC from another nearby oil platform.

The Diving Supervisor used his previous experience to come up with a workable solution in a matter of seconds, and gave the divers the opportunity of saving their lives as opposed to dying from decompression sickness (DCS) as a result of explosive decompression.

Figure 2 summarizes the three different decision making strategies. The first box represents the situation awareness process. Based on the level of risk, the amount of time available, and the degree to which the problem is understood, the most appropriate decision making strategy is then chosen.

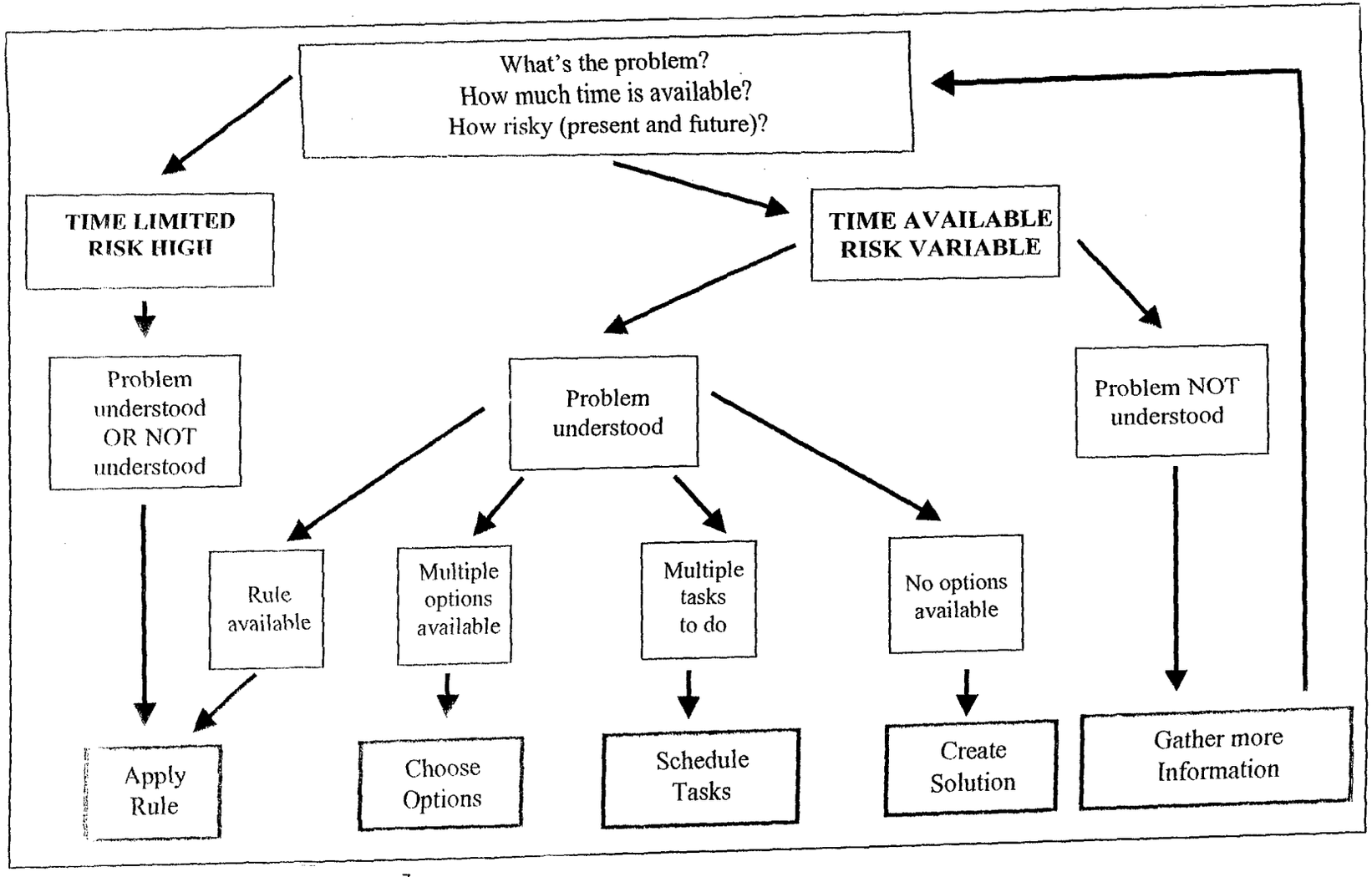

Figure 2. Decision process model.[7]

WHY IS DECISION MAKING IMPORTANT TO NAVY DIVERS?

When conducting a diving operation, every member of a diver team is making decisions. Each of the three decision making strategies (see **DECISION MAKING**) may be used at times during a diving operation.

- Analytical decision making: e.g., when planning a job, or addressing difficulties with a job.
- Rule-based decision making: e.g., when applying operating procedures (OPs) or emergency procedures (EPs).
- Recognition-primed decision making: e.g., when the situation is familiar, or a rule is not available, is not sufficiently specific, or must be adapted to a situation.

MYTH ABOUT DECISION MAKING

There is always a procedure that can be applied in every situation.

Although there are procedures for most emergency situations, it is impossible to preplan for every situation.

OPTIMIZING DECISION MAKING

- Don't assume that you don't have time to make decisions.
- Use the most appropriate decision making strategy for the problem, in terms of the amounts of time and risk available.
- Try not to jump to solutions.
- Review decisions with other team members (time-out).
- Communicate.
- Voice concerns before it is too late.
- Beware of overloading individuals.
- Try to avoid complacency.

TEAMWORKING AND LEADERSHIP

The fact that teamworking is an important skill for effective team performance is not surprising. The consequences of failures of teamwork have been illustrated by many high-profile accidents in complex systems (e.g., the shooting down of a commercial airliner by the *USS Vincennes, CG-49* [1988], the Three Mile Island nuclear plant accident [1979]). Analysis of these accidents identifies three main teamwork problems: (i) a lack of role definition, which allows tasks to "fall through the cracks"; (ii) a lack of explicit coordination, which facilitates a failure to balance goals; and (iii) miscommunication problems.[8]

Leadership is also important to team performance. A study of aircrew performance in a full-mission simulation found that the crews who performed well were led by captains who recognized the value of encouraging communication in the cockpit and the importance of maintaining good interpersonal relations between crew members.[9] Crews who were given constant direction by the commander in a simulated helicopter mission have also been found to perform less well than crews who were given less direction.[10]

WHY ARE TEAMWORKING AND LEADERSHIP IMPORTANT TO NAVY DIVERS?

Effective teamworking and leadership are crucial for a safe and productive dive team. More than 25% of the failures in nontechnical skills identified in Navy diving fatalities can be attributed to breakdowns in teamworking and supervision.[3]

The separate personalities of each member of the dive team must be combined to produce a single effective team that shares the work necessary to perform tasks and the information relevant to those tasks.

MYTHS ABOUT TEAMWORKING AND LEADERSHIP

Junior divers should not question senior team members.

The need for assertive behavior in more junior team members has been sharply highlighted in aviation research. In aviation, the copilots are reluctant to question the captain under emergency conditions, and this lack of assertiveness has been has contributed to aircraft crashes such as those of Tenerife (27 March 1977) and Washington, DC (13 January 1982). Additional if less dramatic evidence comes from a simulator study. When aircraft captains feigned incapacity during a final landing approach, 25% of these planes "crashed" because the copilot failed to take over control.[9]

One leadership style is appropriate for all situations.

No single leadership style is effective in all situations. Effective leadership behavior depends on the leader's personality and skills, the situation, and the competence and motivation of the team being led. Therefore, effective leaders must be able to (i) diagnose the situation (e.g., the task, the time available, and the mood, competence and motivation of the team), (ii) have a range of leadership styles available (e.g., delegative, consultative, directive) and (iii) match their styles to the situation.[11]

TEAMWORKING: DREAM TEAMS

For a team to have basic effectiveness, the following characteristics are required:

- Individual task proficiency
- Clear, concise communication
- Task motivation
- Collective orientation — a belief that the team's goals are more important than those of the individual
- Shared goal and mission

These are the minimum requirements for an effective team, but for enhanced performance, the following are also required:

- Shared understanding of a task
- Shared understanding of other team members' roles and responsibilities
- Team leadership — the leader enables the team to think ahead
- Collective efficacy (a sense of "teamness")
- A sense of anticipation, of "getting ahead of the curve"
- Flexibility (i) to adjust the allocation of resources to fit the task, and (ii) to alter strategies to suit the task
- Implicit communication (an awareness of each other's needs)
- Monitoring of one's own performance

These requirements were made from investigations of more than 300 U.S. Navy teams.[12]

ATTITUDES OF INEFFECTIVE TEAM MEMBERS

The Federal Aviation Administration has outlined five hazardous attitudes of ineffective team member performance.[13] Although based on research with pilots, these hazardous attitudes are also relevant to Navy divers.

1. Antiauthoritarian: "Don't tell me what to do."

This attitude is found in people who do not like to be told what to do. They may resent being told what to do, or they may regard rules, regulations, and procedures as unnecessary. However, listing this as a hazardous attitude is not to say that you should not question authority if you feel that authority is in error.

2. Impulsivity: "Do something — quickly."

This is the attitude of people who just want to react quickly and do anything. They do not stop to think about what to do; they simply do the first thing that occurs to them.

3. Invulnerability: "It won't happen to me."

Many people feel that they will never be involved in an accident. Divers who think this are more likely to take chances and run unwise risks.

> "When anyone asks me how I can best describe my experiences of nearly forty years at sea, I merely say uneventful. I have never been in an accident of any sort worth speaking about. . . . I never saw a wreck and have never been wrecked, nor was I ever in any predicament that threatened to end in disaster of any sort."
>
> CAPT Edward J. Smith (Captain of the *Titanic*)

4. Macho: "I can do it," or "Too much 'Hooyah.'"

People who always want to prove they can do a task may find themselves in a situation that is beyond their abilities and experience.

5. Resignation: "What's the use?"

People with this attitude do not see themselves as making a big difference in what is happening. They leave the actions to others — for better or worse. They may even go along with unreasonable requests because doing so is easier than making a fuss.

SUPERVISION

The supervisor is the key in preventing industrial accidents. Supervisors hold huge influence on issues such as compliance with safety rules, and in terms of safety performance, the most effective offshore oil production supervisors use interpersonal skills more often than less effective supervisors do. When less effective supervisors are not directly involved in an operation, they abdicate responsibility for their subordinates'

safety, focus more on productivity and deadlines than on leadership or responsibility, and feel pressured to get the job done.[14] North Sea divers report that their confidence in their supervisor's ability to manage accident risk is the most important factor in preventing accidents.[15]

In interviews with U.S. Navy divers about near-misses and in an analysis of U.S. Navy diving fatalities, five categories of supervisor failures were identified (see Appendix A). Failures to maintain standards and plan effectively were the most commonly identified supervisor failings.

ASSERTIVENESS AND LISTENING

The results from an attitude survey designed to assess attitudes to factors associated with effective teamworking showed a significant difference in the attitude of second-class divers and first-class divers and Master Divers (MDVs) toward questioning and speaking up. It was found that junior divers *want* to question, but the senior divers *do not want* to be questioned during emergency or normal operations (see Figure 3).[3]

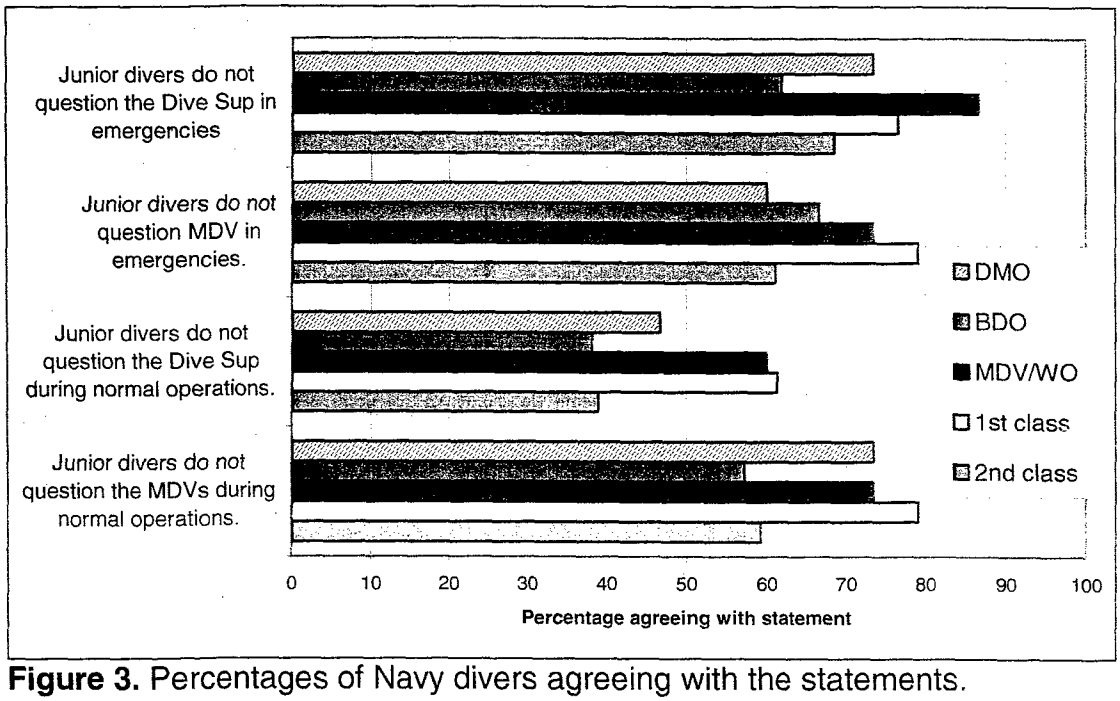

Figure 3. Percentages of Navy divers agreeing with the statements.

A lack of assertiveness was also found to be a key contributor to many U.S. Navy diving accidents. Assertiveness can be understood as a disposition situated between one that is too passive and one that is too aggressive.

> Passive — Failing to stand up for yourself, or standing up for yourself in such a way that others can easily disregard your words or actions.

Assertive — Standing up for yourself in such a way as not to disregard the other person's opinion.

Aggressive — Standing up for yourself, but in such a way as to disregard the other person's opinion.

Research has shown that during communication 7% of the message is verbally communicated, while 93% is transmitted nonverbally. Furthermore, of the 93% nonverbal communication, 38% is through vocal qualities (volume, pitch, rhythm, etc.) and 55% through body movement (mostly facial expressions). Therefore, it is important to attend to both verbal and nonverbal cues when you adopt an assertive stance.[16]

Verbal	Nonverbal
▪ Content: – Decide what you want to say and state it specifically and directly. – Be honest: "I'm damn mad at what you did!" – Stick to the statement; repeat it, if necessary. ▪ Use "I" statements. ▪ Assertively deflect any responses from the other person which might undermine you. ▪ "Broken record technique": – "I hear what you are saying, but..." ▪ Offer a solution. ▪ Obtain feedback.	▪ Eye contact ▪ Body posture ▪ Gestures ▪ Facial expression ▪ Voice tone, inflection, and volume ▪ Timing

However, teaching team members to be assertive will not be effective unless they are also taught to listen. Below is a list of do's and don'ts that will aid in effective listening.

Do	Don't
• Be patient. • Ask questions. • Be supportive. • Paraphrase. • Make eye contact. • Use positive body language.	• Debate what is being said in your mind. • Detour (i.e., look for a key word to change the subject. • Finish the other person's sentence. • Preplan (work out what the person will say next). • Tune out.

FATIGUE

DEFINITION

Everyone knows what it is like to feel fatigue, and everyone has experienced it to some degree. However, researchers have found fatigue to be difficult to define. For the purpose of this description, fatigue can be defined as the state of tiredness that is associated with long hours of work, prolonged periods without sleep, or requirements to work at times that are "out of synch" with the body's biological or circadian rhythm.

Fatigue has been implicated in accidents such as those at Three Mile Island, PA; at Chernobyl, Ukraine; and to the *Exxon-Valdez*. On U.S. highways, fatigue causes 100,000 crashes and 1,500 fatalities each year.[17]

WHY IS FATIGUE IMPORTANT TO NAVY DIVERS?

Divers are often required to work long days, carry out tasks outside normal working hours, or work continuously for a period of days without a break. Navy divers identified fatigue as the second most common cause of diving accidents. Furthermore, when compared to aviation personnel, Navy divers are less aware of the effects of fatigue on their performance.[3]

An Example of Fatigued Navy Divers

On a salvage job it was decided to set up a watch bill to dive around the clock. The job was into the second week of continuous operations. There were many sonar targets, and, as the operation was being carried out in tidal shallow water, it was necessary to move the ship constantly. Since moving the ship required all hands, the divers also participated in this evolution. They were tired and morale was low. The day before the accident they had completed six anchor movements in addition to diving.

MYTHS ABOUT FATIGUE

I am as effective during the middle of the day as I am during the middle of the night.

This is simply not true. There are variations in levels of alertness throughout the day. Even in the best circumstances your alertness at nighttime is less than during the day.

You can train yourself to cope with lack of sleep.

No research suggests that you can train yourself to get by on less sleep through constant sleep deprivation.

CAUSES OF FATIGUE

The causes of fatigue include the obvious one of long hours of work as well as a lack of sleep. Factors such as stress, temperature extremes, noise (>80 dB), hyperbaric pressure, and physical work vibration are all fatiguing. Thus, a combination of cold water, depth, and long hours of work combine to create a fatigue-provoking environment.

CIRCADIAN RHYTHM

The circadian rhythm is a name given to the "internal body clock" that regulates the approximately 24-hour cycle of biological processes in animals and plants. In a typical circadian cycle, performance peaks between 1200 and 2100 (usually around 1600) and falls to a minimum between 0300 and 0600 hours (see Figure 4).

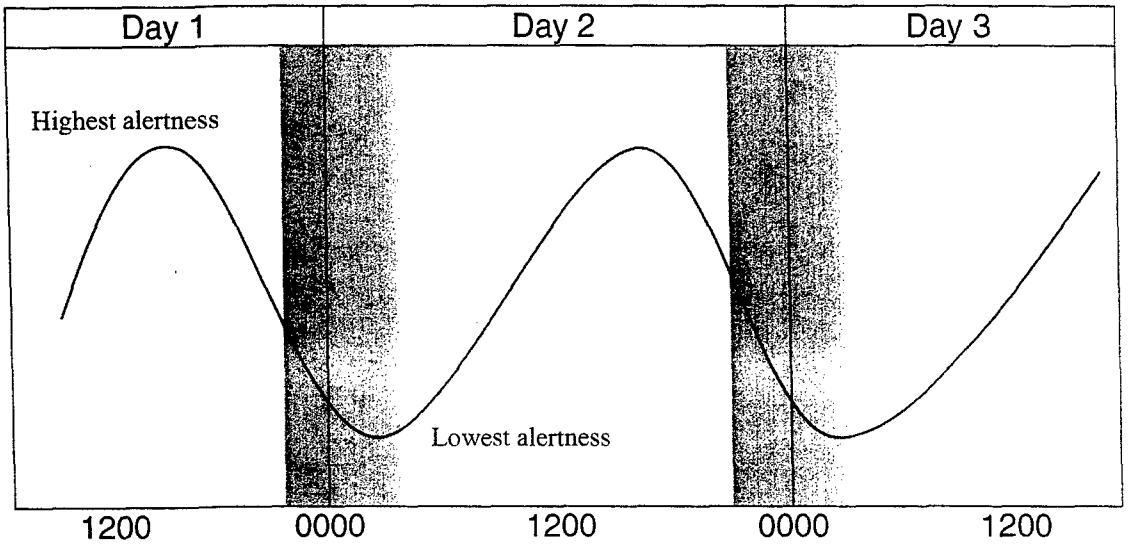

Figure 4. A typical circadian cycle.

Evidence from traffic accidents and occupational accidents shows that a peak tends to occur in the early hours of the morning, when performance is at its lowest. It takes about seven cycles (during which the circadian rhythm is desynchronized) to adjust to working from daytimes to nighttimes. A single period of night work is much better tolerated than three or four consecutive periods of night work.

TYPES OF FATIGUE

A guide on fatigue in Naval aviation identifies three different types of this condition.[18]

Acute
• Produced by physical exertion or sleep loss • Alleviated by a single period of sleep
Chronic
• Results from depression or chronic fatigue syndrome • Treated as a medical or psychological problem
Operational
• Caused by continuous operations • Most commonly seen after 3 to 4 days of heavy tasking • Caused by sleep loss and circadian desynchronization • Not relieved by a single period of sleep

Divers are at risk of both acute and operational fatigue. The latter may be occasioned during a long salvage operation (e.g., that of TWA Flight 800), whereas acute fatigue is a more likely result during a single long day of diving.

EFFECTS OF FATIGUE

The more boring the task, the more likely you are to suffer the effects of fatigue, which are outlined below. In studies of fatigue in a simulated driving task, people were more likely to leave the road when driving on a straight stretch rather than on a corner.[17]

Thinking (cognitive)
• Adverse effect on innovative thinking and flexible decision making • Reduced ability to cope with unforeseen rapid changes • Less able to adjust plans when new information becomes available • Tendency to adopt more rigid thinking and previous solutions
Motor skills
• Less coordination • Poor timing
Communication
• Difficulty in finding and delivering the correct word • Speech is less expressive
Social
• Become withdrawn • More acceptance of own errors • Less tolerant of others • Neglect smaller tasks • Less likely to converse • Increasingly irritable • Increasingly distracted by discomfort
Physiological
• Increased risk of decompression sickness.[19]

The effects of fatigue can also be compared to the effects of alcohol consumption (see Table 1). Even loss of two hours sleep produces a performance decrement equivalent to two or three beers.

Table 1.

Comparison between sleep loss and alcohol consumption.[20]

Sleep Loss (hr)	Equivalent U.S. Beers
8	10–11
6	7–8
4	5–6
2	2–3

FATIGUE COUNTERMEASURES

- **Sleep** is the most effective measure for reducing fatigue. Navy pilots are encouraged to get a minimum of four to five hours of sleep during sustained operations.[18]
- **Napping** is also effective in reducing fatigue. Even a short nap of 10 minutes can improve functioning. However, longer naps can create a hangover — in which the individual may be sluggish or confused for about five minutes after waking up. The guide for flight surgeons recommends that commands should encourage, and at times mandate, napping during sustained operations.[18]
- Fatigue is an aspect of operations that should be **considered and managed during planning**. Attempts should be made to avoid intricate or risky activities between 0300 and 0600.
- Short bouts of light **exercise** should be performed to attempt to maintain alertness.
- **Work standing up**, rather than sitting for long periods of time.
- **Rotate duties, talk to team members, and move around** to attempt to remain engaged in the job and to prevent boredom.
- In military aviation, stimulants or "go pills" such as **dexedrine** (dextroamphetamine) are used to increase alertness and maintain performance. Their use is carefully monitored by the flight surgeon and is authorized only during combat or exceptional circumstances of operational necessity.[18]
- **Caffeine** can be as effective as other medical stimulants in maintaining performance when you are fatigued. Caffeine is most effective for people who do not normally consume large quantities on a daily basis. Two hundred milligrams of caffeine (one small cup) is recommended for consumption every two hours up to five hours before the next sleep break.
- **Monitor** team members for signs of fatigue.

I am immune to the effects of stress. The more pressure, the better I operate.

No one is immune to stress; everyone has a breaking point. However, stress up to a certain level can be exhilarating and can have a positive effect on performance. Nevertheless, if the demands continue to increase, performance will be negatively affected.

I can leave my personal problems at home when I start work.

Problems at home cannot simply be forgotten as soon as you start work. Should someone whose partner and children have just left him or her be the person whom you want to supervise an HeO_2 dive or to predive your dive rig?

If you are suffering from stress, the best thing to do is ignore it.

This "bottling up" can work for awhile, but a time may come when everything boils over and you are no longer able to cope. Do you really want to be on a deployment and have one of your team members suffer a catastrophic breakdown?

THEORY OF STRESS

This theoretical model of stress can be portrayed as a balance mechanism (Figure 5), a model applicable to both chronic and acute stress.

When the available resources are judged to be equal to the demands, then the individual feels in control and comfortable: the scale is horizontal. In this state, moderate increases in demand may actually increase motivation and performance, since low levels of stress have a beneficial effect on performance. But when stressors, the *perceived* demands, outweigh the *perceived* resources to cope with those demands, stress reactions begin to occur. These reactions — a complex and interacting package of responses with behavioral, emotional, somatic (physical), and thinking effects — then feed back into the individual's assessment of the situation. For instance, an awareness of added symptoms of stress increases one's sense of a loss of control, increases the imbalance, and thereby increases the individual's stress.

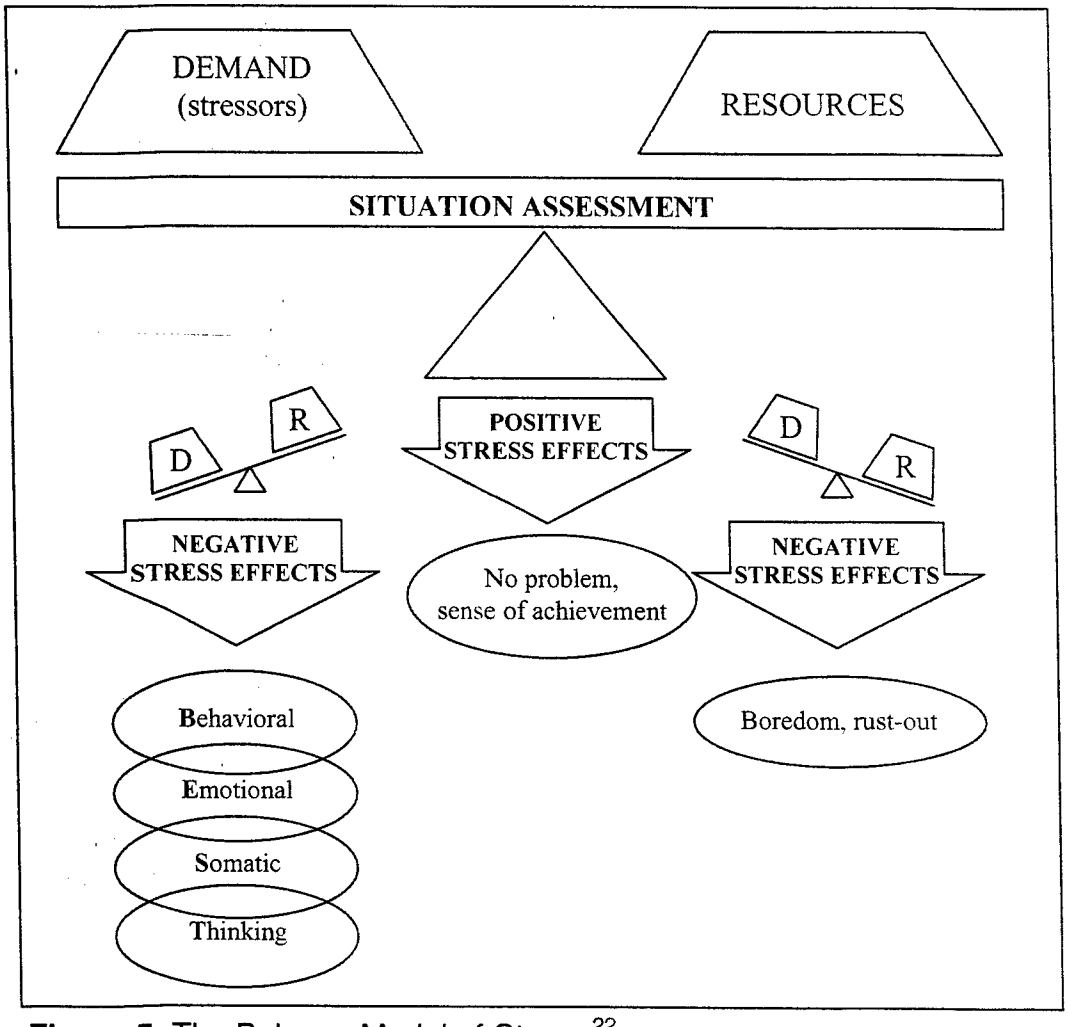

Figure 5. The Balance Model of Stress.[22]

The individual's *perception* of the demands on him or her and his/her capabilities to meet these demands are crucial. No absolute level of demands appears to be important. Only the discrepancy that exists between the individual's perception of the demands and his or her perceived ability to cope is significant. Critical appraisal of demands and coping resources is based on an array of factors such as previous experience, training, and personality. Consequently, one diver faced with a particular incident may feel calm, confident, and totally in control; another diver in the same situation may be uneasy, irritable, and losing a grasp of the situation.

CHRONIC STRESS

In the developed world, chronic stress is the greatest challenge to the health of working people and to the healthiness of their work organizations. Furthermore, stress-related problems are the second most commonly reported cause of occupational ill health.

Everyone has a level of stress at which he or she is unable to cope. However, the individual differences are large.

The relationship between stress response and performance is typically depicted as an inverted "U" curve (Figure 6). Performance improves with increases in stress; however, an optimal range exists where performance peaks. With additional increases in demands, performance decreases. This curve is not the same for every individual — e.g., some people have lower tolerances to stress — and even for one person it may vary from day to day: e.g., if one does not get sufficient sleep, his ability will be reduced. People probably should not be operating at the top of the curve without a break for days at a time.

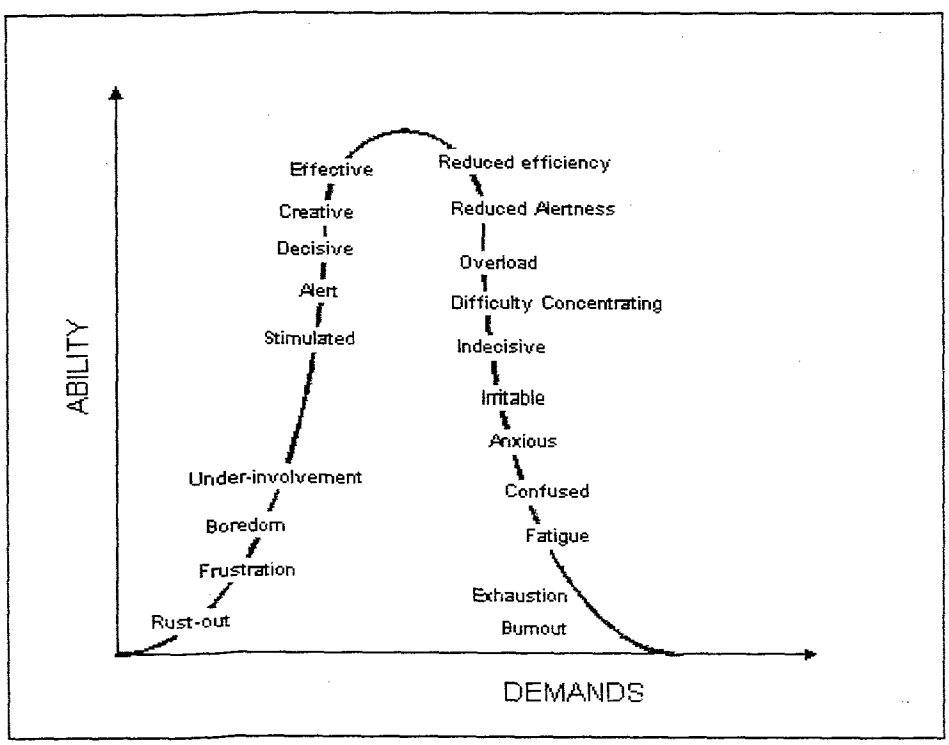

Figure 6. Stress and performance curve.

A model of chronic stress (Figure 7) consists of stressors, mediating factors that can either increase or decrease stress effects (Table 2), symptoms of stress, and disease.

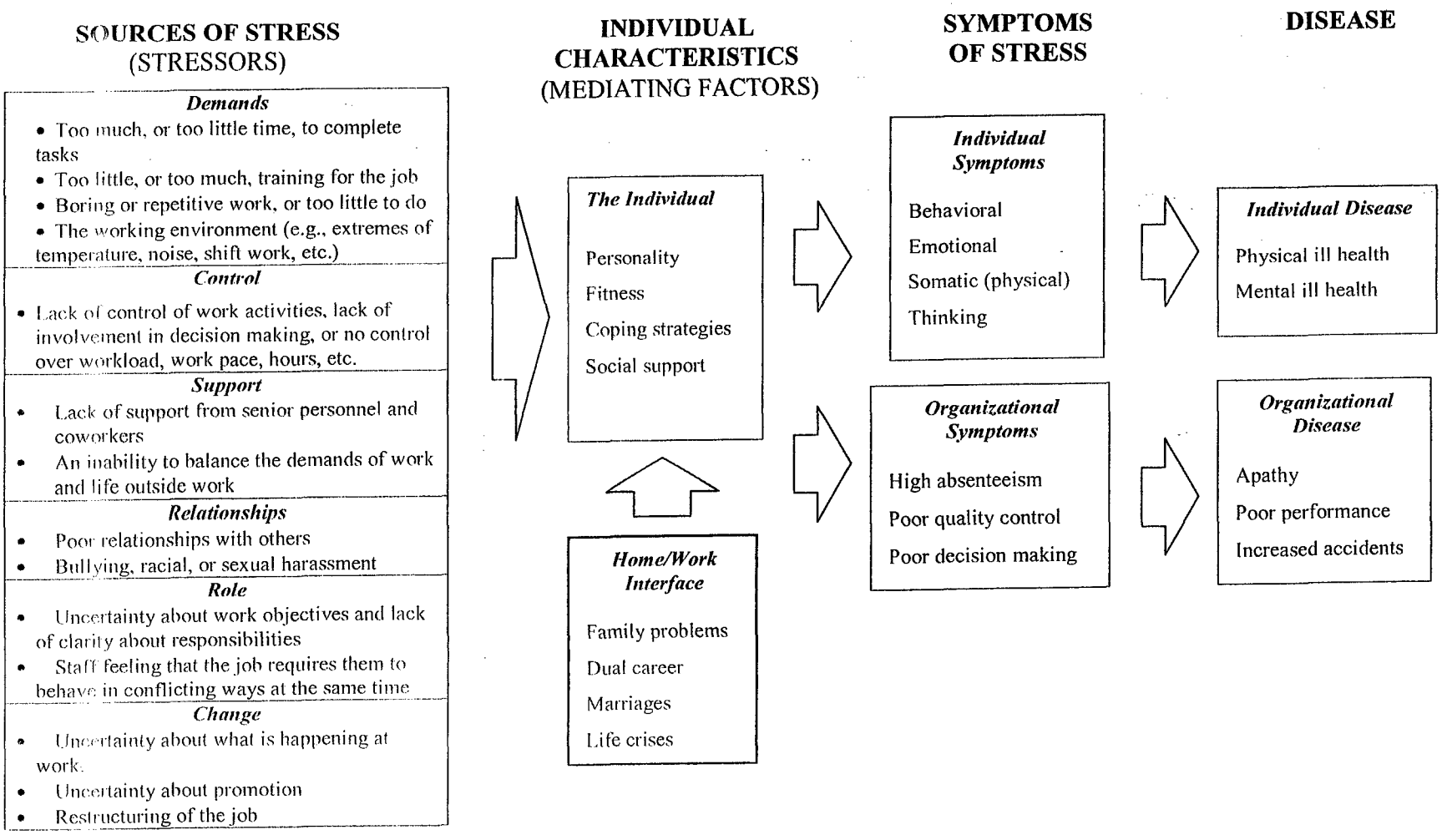

Figure 7. Model of chronic stress.[23]

Table 2.

Chronic stress mediating factors.

Mediating factor	Explanation
Personality	Some people are just better able to cope with a high-stress work environment. However, research findings about how personality acts to mediate stress are not clear.
Social Support	In almost all models of occupational stress, social support — from family, friends, and colleagues — is a mediating variable.
Fitness	Fitness and general well being is a good buffer against stress. Feelings of tiredness or ailments such as cold or flu are well-known sources of increased sensitivity to stress.
Coping Strategies	Whether people experience stress depends largely on their coping strategies.
Change	Any change in the routines of a life can be stressful — even a positive change.
Home/Work Interface	Managing the demands of work and family life, particularly in terms of time commitment, can also be a stressor. Long periods of deployment, or families in which both parents work, can add to levels of chronic stress.

No single way exists to identify whether a colleague is suffering from chronic stress. Since people often may not wish to admit to themselves, or to others, that they are suffering from stress, this reluctance can then contribute to a much more catastrophic result than if the problem could be easily identified. Indicators of chronic stress can be divided into four categories (Table 3).

Table 3

The BEST indicators of chronic stress.

Category	Indicators
Behavioral	Apathy Reduced productivity Absenteeism Abuse of drugs (e.g., increased alcohol use or smoking) Hostile behavior
Emotional	Expressions of anxiety and hopelessness Irritability Appearance of boredom or apathy Cynicism and resentfulness
Somatic (physical)	Health complaints such as headaches, chest pains, or stomach complaints Decline in physical appearance Chronic fatigue Frequent infections
Thinking	Impaired decision making Lack of concentration

Once symptoms of stress are present, they can result in disease at both an individual and a team level. Diseases that are associated with chronic stress include bronchitis, coronary heart disease, mental illness (e.g., depression), thyroid disorders, skin diseases, types of rheumatoid arthritis, obesity, tuberculosis, headaches and migraines, peptic ulcers, and ulcerative colitis.[22]

At the team level, even if one member of a dive team is suffering from chronic stress, productivity can be reduced and a likelihood of mistakes can increase. Evidence suggests that individuals who are experiencing chronic stress are increasingly likely to be involved in an accident. To illustrate, retrospective studies of U.S. Navy pilots have linked stressors such as career strain, financial difficulties, and interpersonal problems to aircraft mishaps.[24]

DEALING WITH CHRONIC STRESS

All members of the dive team should monitor themselves and their team members for signs of chronic stress. Research generally divides techniques for preventing chronic stress into three types:

1. Attempts to modify or eliminate sources of stress that are intrinsic to the work environment. Obviously certain stressors (abnormal hours, cold water, etc.) are just part of the job of diving and cannot be changed. However, some stressors

(e.g., work schedule) may be possible to manage, particularly by individuals in senior positions.

2. Use stress management techniques. Typical stress management techniques include:
   - Muscle relaxation — this involves tensing (for 5 to 10 seconds) and releasing one muscle group at a time in a specific order, generally starting with the lower extremities and finishing with muscles of the face, abdomen, and chest.
   - Meditation — the purpose of this is to quiet the mind, emotions, and body.
   - Biofeedback — this is a training technique in which an individual learns to control the physiological reactions (e.g., increased heart rate and muscle tension) to stress.
   - Cognitive-behavioral stress management — this involves changing the way the individual thinks about stress. The aim is to help him or her to recognize negative or inaccurate thoughts and to alter the behavioral responses to these thoughts.

   Research has found that a combination of these techniques is most effective in reducing the effects of stress.

3. Those who think they are suffering from chronic stress that is affecting their job performance should talk to their supervisor, corpsman, or diving medical officer (DMO). They may be referred for professional counselling for work or personal problems. If any member of the dive team is suffering from chronic stress, he or she should be directed to seek help.

ACUTE STRESS

Divers are at risk not only from chronic stressors but also from acute stressors such as periods of high workload, emergencies, attempts to diagnose an unusual problem, or high costs of failure. The principal cause of death in recreational divers is panic or loss of control. In more than 60% of scuba diving fatalities the cause is listed as drowning, which is usually caused by specific problems such as a lack of air; entanglement in fishing nets, rope, or kelp; air embolism; narcosis; and panic.[25] A model for acute stress (Figure 8) consists of the same framework of sources, mediating factors, symptoms, and disease as the model of chronic stress (Figure 7) but is specific to acute stress situations.

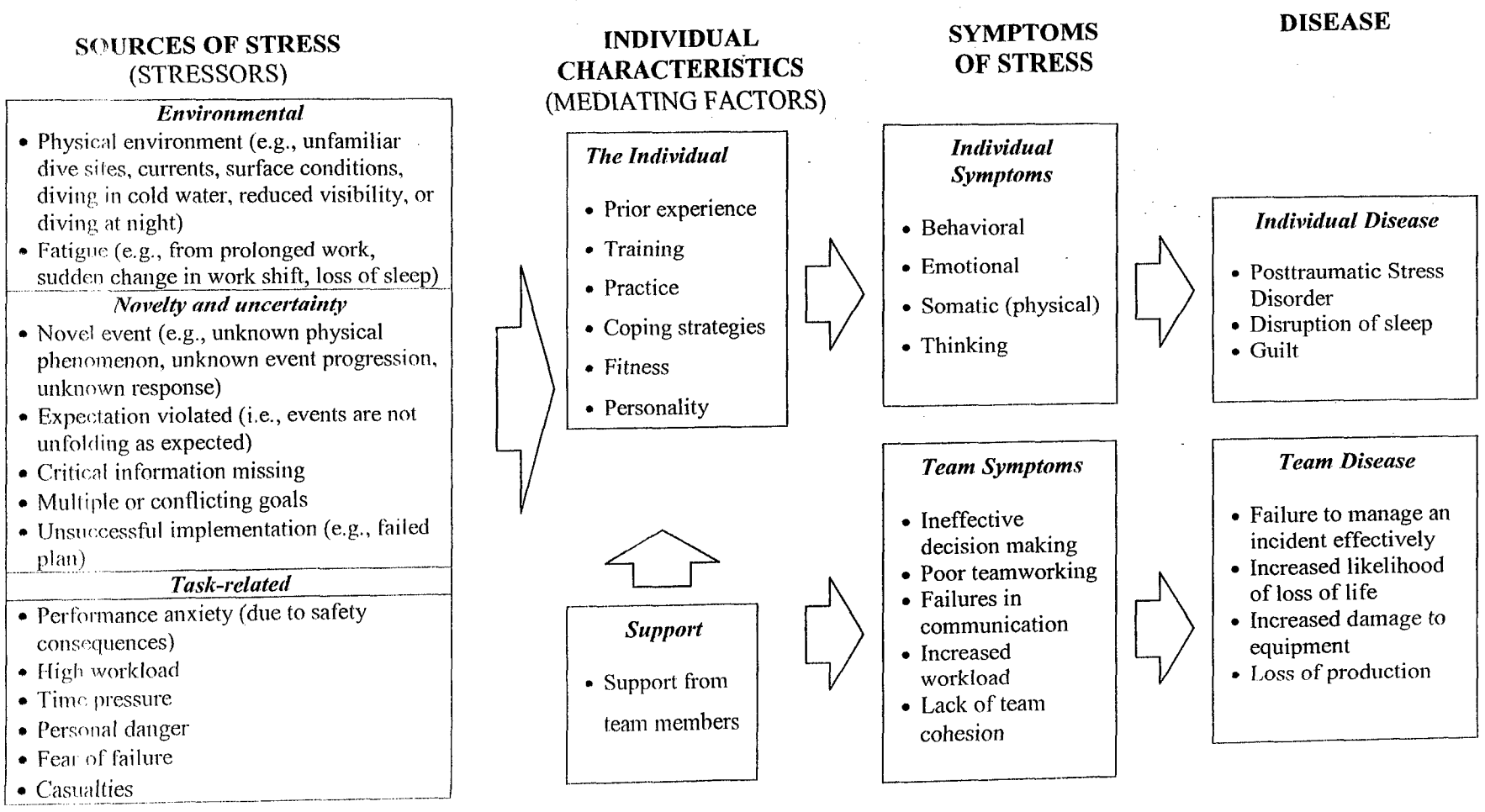

Figure 8. Model of acute stress.

The indicators of acute stress include:

Behavioral	
Fight/flight: • Hyperactivity • Anger • Argumentativeness • Irritability • Jumpiness • Aggressiveness • Swearing • Emotional outbursts	Freezing: becoming • Withdrawn ("switched off") • Detached • Apathetic • Disengaged from surrounding activities
Emotional	
• Fear • Anxiety • Panic	• Fear of failure • Vulnerability • Loss of control
Somatic (physical)	
• Energy surge • Increasing heart rate • Sweating	• Muscle tension (trembling) • Heightened sensitivity (e.g., to noise) • Effects on digestion (butterflies in stomach)

Thinking (cognitive)	
Indicators	Descriptions
Impairment of memory	• Prone to distraction • Confirmation bias (tending to ignore information that does not support following a chosen model or course of action • Information overload • Task shedding (the abandonment of certain tasks when stress or workload makes it difficult to concentrate on all of the tasks simultaneously)
Reduced concentration	• Difficulty prioritizing • Preoccupation with trivia • Perceptual tunneling (attention becoming narrowly focused on salient cues)
Difficulty in decision making	• Availability bias (resorting to familiar routines and considering plans that are only immediately available in memory) • "Stalling thinking" — mind blank

For the individual, involvement in a critical incident such as a death of a team member, a near miss, or an injury can have a profound effect and can result in posttraumatic stress disorder, a result that may necessitate some counseling or specialized debriefing. For the team, acute stress can result in a failure to manage a situation effectively and can end in loss of life, equipment damage, or loss of equipment.

Effects of Acute Stress

A dive team was carrying out a simulated bottom search with scuba at 80 fsw. The dive was being directed by a new diving officer supervising his first working dive.

One diver, who was straight out of dive school and had never previously dove in the conditions (a strong current), had been deployed. After about 30 minutes, the diver was no longer giving line-pull signals. The Diving Supervisor finally deployed the standby diver, but after 5 to 10 minutes into this dive, no line-pull signals were being received from him.

After a period of time (more than an hour from the first diver's entry into the water), the team hauled up the descent line and found both divers fouled in the lines. The standby diver was unconscious but breathing; the first diver had no vital signs. The supervisor called the chamber, and told the technicians that the team was on the way.

A civilian air ambulance was called for the first diver — who, due to a miscommunication, was taken to a local hospital rather than the chamber. The standby diver was taken by boat directly to the chamber on the ship. After recovering the first diver's vital signs, the hospital eventually realized that he needed recompression treatment and flew him to the base. About 50 minutes after being pulled from the water he was in the chamber and pressed. The first diver had intermittent vital signs but died 6 hours into treatment. The standby diver recovered fully.

The inexperienced Diving Supervisor appeared to be displaying a number of symptoms of acute stress. The failure to respond to the lack of line-pull signals from the stricken diver or standby are indicative of a number of failures due to acute stress:

- Freezing and stalled thinking—unable to make a decision
- Confirmation and availability bias—ignoring the possibility that the divers could be in extreme difficulty, as this is simply too overwhelming and unpleasant to consider.

Further, the failure of the helicopter pilot to take the diver to the correct hospital could also be attributed to the effects of acute stress on concentration and the failure to communicate the required action.

MANAGING ACUTE STRESS

1. Practice performing in simulated stressful diving scenarios. The only way to see how dive team members will cope with stress is to put them into a stressful situation. The best way to improve performance in stressful situations is to conduct regular drills in which individuals are forced to react quickly and think on their feet.

2. Practice using cognitive control techniques. This technique trains individuals to regulate emotions (e.g., worry) and distracting thoughts so that they maintain concentration on the task. They can become aware of what their bodies are telling them. If their muscles are very tense or their hearts are racing, they can attempt to regain control of them by briefly stepping away from a situation, if they feel overwhelmed.

3. Use a procedure to regulate stress reactions.
   - **Stop** — Stressed personnel should stop what they are doing.
   - **Breathe** — They should focus on slowing their breathing rate, and calming down. In most diving fatalities due to drowning, ample air is still available to the diver.
   - **Think** — They should think about the problem and decide what they are going to do next.
   - **Act** — They should select an option and, finally, act on it.

4. Monitor team members for signs of acute stress. If any member of the team is failing to perform effectively, monitoring will enhance mission success and safety. As a Diving Supervisor or Master Diver, if you see signs that a member of the dive side is suffering from acute stress, you may attempt to give him or her a break for a couple minutes or move him or her into a less critical role.

5. Debrief the dive team after a stressful event. Debriefing has been shown to be a highly effective strategy to help team members to develop skills and understanding.[26] Debriefing allows the team members to discuss what has happened, both good and bad, and to realize that it is normal to experience stress in that situation. Further, if people are placed in a stressful situation (e.g., Master Diver evals) and do not perform well, then they are unlikely to cope well when faced with another stressful situation unless they are given a thorough debriefing about what went wrong, why it went wrong, and what they can do to avoid the same mistakes in the future (recall the balance model of stress in Figure 5).

CONCLUSION

Navy diving is remarkably safe, despite the high-risk environment in which divers operate. Nevertheless, diving accidents and near misses do occur. Although it has been a few years since the last fatal U.S. Navy diving accident, statistics dictate that it is only a matter of time until the next. Divers in the fleet are regularly involved in diving mishaps or near-misses in which it is only luck, a few inches, or the fast reactions of the dive team that prevented a diver from suffering a serious injury or being killed.

Other high-risk industries (e.g., aviation, medicine, nuclear power generation, commercial shipping, offshore oil production[27]) have recognized the impact that failures in nontechnical skills have on safety and have taken measures to attempt to improve the nontechnical skills of their workforce. This guide has summarized the research carried out in other industries and applied it to the specific types of operations and environments in which U.S. Navy divers work.

The use of nontechnical skills is relevant not just to safety and accident prevention. Superior teamworking and leadership benefits job performance: the effective use of nontechnical skills will allow a job to be done more efficiently and quickly.

Therefore, next time you are on the side or in the water, be sure to consider the *technical* aspects of performing your job, but don't forget the equally important *nontechnical* aspects of the task.

REFERENCES

1. Naval Safety Center, *Naval Flight Surgeon's Pocket Reference to Aircraft Mishap Investigation* (Norfolk, VA: Navy Safety Center, 2001).

2. J. Reason, *Human Error* (Cambridge, U.K.: Cambridge University Press, 1990).

3. P. O'Connor, *An Investigation of the Nontechnical Skills Required to Maximize the Safety and Productivity of U.S. Navy Divers*, NEDU TR 05-03, Navy Experimental Diving Unit, April 2005.

4. M. Endsley, "Design and Evaluation for Situation Awareness Enhancement," in Human Factors and Ergonomics Society, *Proceedings of the 31st Annual Meeting of the Human Factors and Ergonomics Society* (Santa Monica, CA: Human Factors and Ergonomics Society, 1988), pp. 1388–1392.

5. M. Endsley, "Automation and Situation Awareness," in R. Parasuraman and M. Mouloua, eds., *Automation and Human Performance: Theory and Application* (Mahwah, NJ: Lawrence Erlbaum Associates, 1996), pp. 163–181.

6. G. Klein, *The Power of Intuition* (New York, NY: Doubleday, 2003).

7. J. Orasanu, "Training for Aviation Decision Making: The Naturalistic Decision Making Perspective," in Human Factors and Ergonomics Society, *Proceedings of the 39th Annual Meeting of the Human Factors and Ergonomics Society* (Santa Monica, CA: Human Factors and Ergonomics Society, 1995), pp. 1258–1263.

8. M. L. Thordsen, G. A. Klein, and S. Wolf, *Observing Team Co-ordination within Army Rotary-Wing Aircraft Crews* (Yellow Springs, OH: Klein Associates Inc., 1990).

9. R. Helmreich, "Cockpit Management Attitudes," *Human Factors*, Vol. 26 (1984), pp. 583–589.

10. H. C. Foushee and R. L. Helmreich, "Group Interactions and Flight Crew Performance," in E. L. Wiener and D. C. Nagel, eds., *Human Factors in Aviation* (San Diego, CA: Academic Press, 1988), pp. 189–227.

11. R. Flin, *Sitting in the Hot Seat: Leaders and Teams for Critical Incident Management* (Chichester, U.K.: John Wiley & Sons, 1996).

12. E. Salas and J. Cannon-Bowers, "Making of a Dream Team," presented at the American Psychological Society Conference, Toronto, Canada, August 1993.

13. Federal Aviation Authority, *Introduction to Pilot Judgment* (Washington, DC: Federal Aviation Authority, 1991).

14. R. Flin, K. Mearns, M. Fleming, and R. Gordon, *Risk Perception and Safety in the Offshore Oil and Gas Industry* (Suffolk, U.K.: HSE Books, 1996).

15. L. M. Osman, W. Adie, and J. Cairns, *Attitudes to Safety Culture among Professional Divers and Offshore Workers* (Suffolk, U.K.: HSE Books, 2003).

16. M. Koneya and A. Barbour, *Louder Than Words: Nonverbal Communication* (Columbus, OH: Merrill, 1976).

17. J. A. Caldwell and J. L. Caldwell, *Fatigue in Aviation* (Burlington, VT: Ashgate, 2003).

18. Naval Strike and Air Warfare Center, *Performance Maintenance During Continuous Flight Operations: A Guide for Flight Surgeons*, NAVMED P-6410 (Fallon, NV: NSAWC, 2000).

19. Commander, Naval Sea Systems Command, *U.S. Navy Diving Manual, Revision 4.* (Arlington, VA: Naval Sea Systems Command, 1999).

20. T. Roehrs, E. Burduvali, A. Bonahoom, C. Drake, and T. Roth, "Ethanol and Sleep Loss: A 'Dose' Comparison of Impairing Effects," *Sleep*, Vol. 26, No. 8 (2003), pp. 981–985.

21. E. Salas, J. E. Driskell, and S. Hughes, "Introduction: The Study of Stress and Human Performance," in J. Driskell and E. Salas, eds., *Stress and Performance* (Mahwah, NJ: Lawrence Erlbaum Associates, 1996), pp. 1–46.

22. T. Cox, *Stress Research and Stress Management: Putting Theory to Work* (Suffolk, U.K.: HSE Books, 1993).

23. C. L. Cooper, R. D. Cooper, and L. H. Eake, *Living with Stress* (London, U.K.: Penguin Books, 1988).

24. R. A. Alkov, M. S. Borowsky, and J. A. Gaynor, "Stress Coping and the U.S. Navy Factor Mishap," *Aviation, Space, and Environmental Medicine*, Vol. 53 (1982), pp. 1112–1115.

25. W. P. Morgan, "Anxiety and Panic in Recreational Scuba Divers," *Sports Medicine*, Vol. 20, No. 6 (1995), pp. 398–421.

26. S. M. Norton, "Peer Assessment of Performance and Ability: An Exploratory Meta-analysis of Statistical Artifacts and Contextual Moderators", *Journal of Business and Psychology*, 6 (1992), pp. 387–399.

27. R. Flin, P. O' Connor, and K. Mearns, "Crew Resource Management: Improving Safety in High Reliability Industries," *Team Performance Management*, 8 (2002), pp. 68–78.

APPENDIX A. DIVER NONTECHNICAL SKILLS FRAMEWORK

Category	Element	Description	Example
Situation Awareness	Anticipation	Forward planning is completed to identify and discuss contingency strategies and/or possible future problems.	*Started screw change, he had done a dozen in the past.*
	Problem definition/ diagnosis	Information is gathered to identify a problem and its causal factors.	*They did not want to admit something had gone bad.*
	Risk and time assessment	An accurate assessment of risk and time is completed (weather, sea state, time available, equipment, etc.)	*The whole evolution felt unsafe.*
	Dive status awareness	Every team member has an accurate awareness of how a dive is progressing.	*After about 30 minutes, getting no line-pull signals.*
	Task awareness	The team member has an accurate awareness of the task in which he/she is engaged and of his/her role in the dive.	*Told he was red diver, then told he was yellow. Went over to yellow bike, then told he was red diver.*
	Concentration/ avoiding distraction	The team member is able to give the attention necessary to perform the task.	*The supervisor said to load a HeO_2 bottle, but he loaded a N_2O_2 bottle instead.*
Decision Making	Procedural adherence	The procedures are followed correctly and are appropriate for the task being carried out.	*The correct procedure was not followed to check the equipment.*
	Outcome review	The outcome of a solution is checked against the predefined goal.	*Nothing was learned from the incident.*
Communication	Assertiveness/ speaking up	Ideas and observations are communicated in a manner that is persuasive to other team members.	*He suggested diving would not be a good idea, but did not want to push it as he knew he would be overruled.*
	Information exchange	Information is clearly and accurately exchanged between team members.	*He would not listen to recommendations.*
Team cohesion	Team climate	Team members are aware of the competencies of their teammates, trust each other, and have a positive attitude toward being a member of the team.	*He requested extra divers, but they were reluctant to work outside normal working hours.*
	Conflict solving	Conflicts are resolved in a way that minimizes harm done to both parties.	*The shipyard viewed them as taking their work so they were not particularly helpful.*

Supervision/ Leadership	Appropriate use of authority	The supervisor adequately balances assertiveness and team member participation.	*He told the divers they were a bunch of pussies and he would get in the water if they were too scared.*
	Maintaining standards	The supervisor ensures the dive team complies with standard operating procedures and intervenes if required.	*They should have used the MK 21 for this evolution.*
	Planning and coordination	The appropriate personnel, resources, and techniques are selected to complete a task.	*There was some question about splashing a new diver who had never been in these conditions before.*
	Workload management	Tasks and resources are shared in order to achieve top performance and avoid workload peaks and dips.	*They knew there were jobs piling up behind them.*
	Choice of leadership style	A leadership style is used that promotes a safe working environment and is appropriate to the dive team, task, and urgency of the situation.	*The MDV was a cowboy.*
Personal resources	Identifying and managing stress	Signs of stress are communicated and taken into account.	*There was a lot of tension topside.*
	Identifying and managing fatigue	Signs of fatigue are communicated and taken into account.	*They were diving around the clock, so the divers were tired.*
	Physical and mental fitness	Team members are sufficiently fit, physically and mentally, to perform the assigned tasks.	*He felt as if he was in a daze.*
	Experience/ training	The team members involved in the operation have sufficient experience and training.	*For many of the divers it was the first time in a dry suit.*